ENVIRONMENTAL MONITORING OF FOREST INSECT CONTROL OPERATIONS (EMOFICO)

1986 REPORT

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ABSTRACT

This multi-disciplinary compilation of 12 reports concerns primarily the environmental monitoring of the spruce budworm aerial spray operations in New Brunswick in 1986 with some information from other jurisdictions. The 15 authors report on the operational and regulatory aspects of the spray program, and on the insecticide ecology in ecosystems associated with spruce-fir forests which include studies on songbirds, freshwater fauna, toxicology, insecticide analysis, insecticide transport, persistence and contamination. The insecticides studied were fenitrothion, aminocarb, mexacarbate and Bacillus thuringiensis.

TABLE OF CONTENTS

	Page
ABSTRACT	i
FOREWORD	iv
RECOMMENDATIONS	v
OPERATIONAL SPRAYING	1
1986 spruce budworm protection program in New Brunswick. N. Carter	1
1986 Insect Control Operations J. D. Irving Limited. B. Brunsdon	11
EXPERIMENTAL SPRAYING	14
Review of research and development programs conducted in New Brunswick in 1986 to evaluate pesticides and tactics against the spruce budworm (C. fumiferana) and the spruce budmoth (Z. canadensis). E. G. Kettela	14
TERRESTRIAL IMPACTS	18
Effects of Zectran (mexacarbate) and fenitrothion on forest songbirds: a summary report of Canadian Wildlife Service (Atlantic Region) field studies in 1986. D.G. Busby, P. A. Pearce, and N. R. Garrity	18

Forest Pest Management Institute stance on the use of fenitrothion in forest protection operations relative to its impact on forest songbirds.
G. W. Green..... 25

Budworm behaviour and their microhabitat in balsam fir during spray operations.
P. C.Nigam..... 35

AQUATIC IMPACTS 36

The effects of fenitrothion on zooplankton in bog ponds.
D.C. Eidt, W. L. Fairchild, and C. C. A. Weaver..... 36

Effects of forest spraying on the invertebrate community of bog ponds.
W. L. Fairchild and D. C. Eidt..... 36

REGULATORY ACTIVITIES..... 39

Operational budworm monitoring.
W.A. Sexsmith..... 39

MONITORING PROGRAMS IN OTHER JURISDICTIONS 42

Hemlock looper environmental monitoring program in Newfoundland.
M. Cahill..... 42

Environmental monitoring in Maine.
S. Oliveri..... 43

Environmental monitoring and quality control of aerial spraying of insecticides against the spruce budworm in Quebec in 1986.
P.- M. Marotte and A. Cimon..... 44

RECENT PUBLICATIONS..... 54

FOREWORD

The New Brunswick Committee for Environmental Monitoring of Forest Insect Control Operations (EMOFICO) is an informal association of biologists, foresters, environmental specialists and chemists from federal and provincial governments, industry and universities. Its prime objective is to exchange information on the impact of operational spray programs on non-target organisms and ecological processes in forest and adjacent ecosystems. By implication this includes experimental sprays and complementary laboratory studies. Efficacy is also considered, insofar as it relates to environmental effects. The potential consequences of forest spray programs for human health are beyond the Committee's terms of reference. Although the Committee's focus is on spray activities in New Brunswick, it seeks to keep aware of forest insect control operations and related environmental studies in the Atlantic region as well as in Quebec and Maine.

The Committee assumed its present name and structure in 1976, and has been under the aegis of the Department of Municipal Affairs and Environment (formerly the Department of the Environment) since 1980. The 1986 report, like its predecessors, is aimed at a broad readership - scientists, regulators, resource managers and, not the least important, the public. It consists essentially of preliminary reports and abstracts of reports completed.

For further information on the role of the New Brunswick Committee for EMOFICO as well as an instructive statement on insecticide ecology, the reader is referred to the Committee's combined 1978-1979 report.

Steering Committee

D. I. Besner (N. B. Department of Municipal Affairs and Environment)
D. C. Eidt (Canadian Forestry Service)
P. A. Pearce (Canadian Wildlife Service)
W. A. Sexsmith (N. B. Department of Municipal Affairs and Environment)

RECOMMENDATIONS

A consensus of the EMOFICO Committee:

It is recommended:

(1) that, inasmuch as the operational use of fenitrothion at conventional dosages sometimes adversely affects birds, pollinating insects and aquatic invertebrates, more environmentally acceptable alternatives to fenitrothion and to present use patterns of fenitrothion must be actively sought;

(2) that, inasmuch as the incidence of certain effects of fenitrothion on birds, pollinating insects and aquatic invertebrates may be related to greater than expected spray deposit, the frequency with which that occurs should be determined;

(3) that the impact of forest spraying on the pollination of forest plants be further investigated;

(4) that a review be conducted of the available information on the environmental effects of Bacillus thuringiensis in order that data gaps may be identified;

(5) that the environmental implications of the potential use of mexacarbate be reviewed and a statement be prepared on its environmental acceptability; and

(6) that regulatory agencies continue to review the rationale for the specifications for buffer zones, recognizing that spray technology is changing.

OPERATIONAL SPRAYING

1986 SPRUCE BUDWORM PROTECTION PROGRAM IN NEW BRUNSWICK

N. Carter

1986 Spray Program

The 1986 spruce budworm spray program (Figure 1) conducted by Forest Protection Limited, in New Brunswick covered approximately 496 000 hectares. This represents a 29% reduction from 1985. Of the total area treated, about 90% was in the industrial part of the program (i.e. beyond 1.6 km from habitation) and the balance was in the non-industrial sector consisting primarily of small private woodlots.

Chemical insecticides were used over 78% of the program and B.t. on the remainder. Aminocarb (Matacil 180 F) was sprayed in double applications over 126 000 ha; fenitrothion (Sumithion) in double applications over 118 000 ha; and 141 000 ha received a single application of one chemical followed by the other. B.t. was sprayed over 111 000 ha (Table 1). Most of the chemical treatments were applied in water-based formulations and B.t. was applied undiluted.

A total of 63 aircraft were involved in the program, 29 of which were spray planes, including nine TBMs, 16 agricultural-type spray aircraft, and four helicopters (Bell 206s) (Table 2). TBMs were restricted to the industrial part of the program and sprayed 64% of the total area.

The first blocks were opened for spraying on May 24th. After a short weather delay spray operations commenced on the morning of May 26th. Curiously, the commencement date was the same as in the past two years, yet later than in the past. Fortunately, however, acceptable spray weather occurred most mornings and evenings throughout the program and resulted in minimum delays of treatments. All chemical treatments

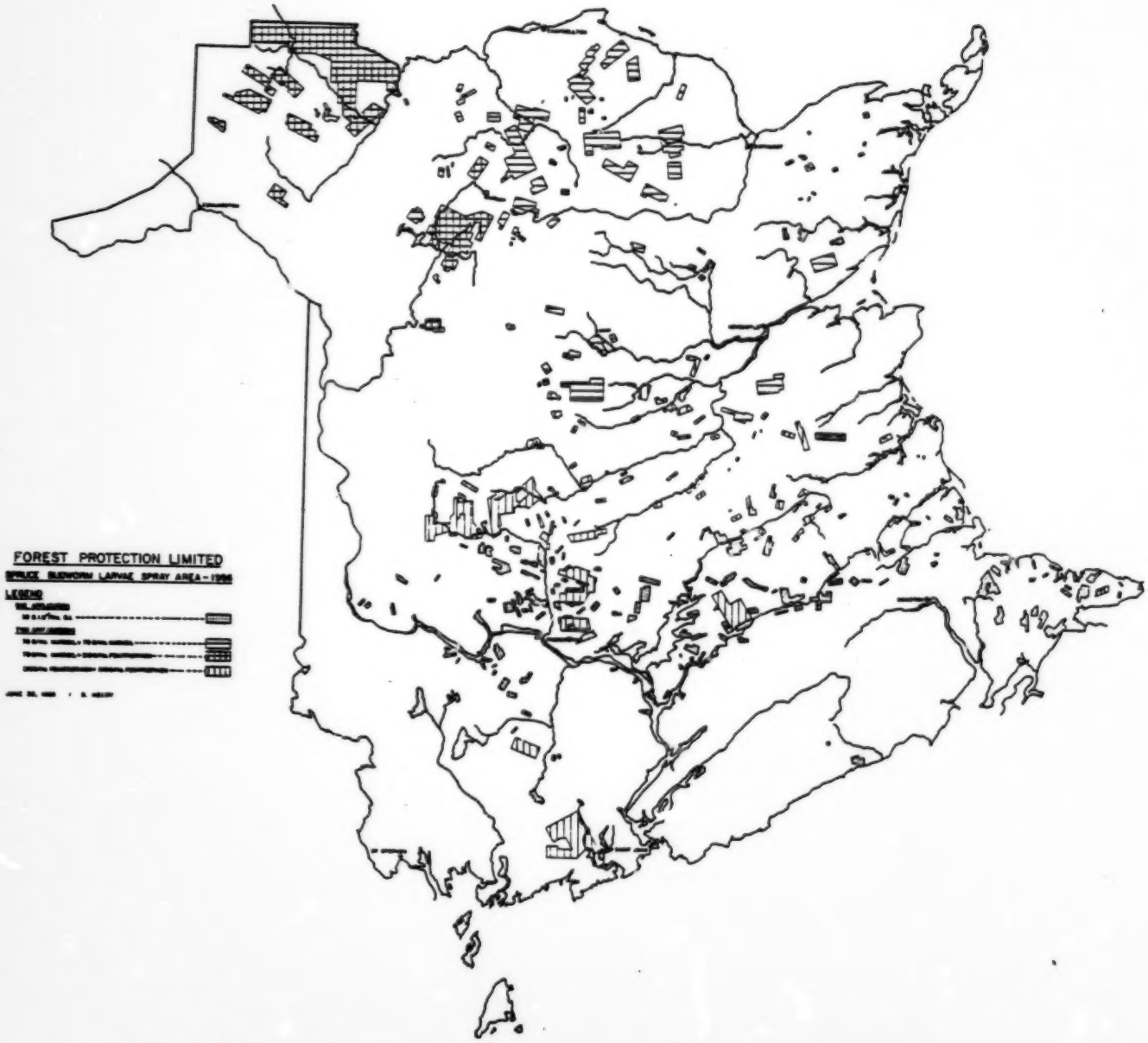

Figure 1. Distribution of blocks treated in the 1986 Spruce Budworm Spray Program in New Brunswick.

Table 1. Areas treated by Forest Protection Limited for spruce budworm control in 1986 in New Brunswick*

Treatment	Hectares Thousands	Acres Thousands	Aircraft Type
One Application			
30 B.I.U./ha B.t.	111.5	275.4	Ag Cat, Ag Truck Bell 206
SUB-TOTAL	111.5	275.4	
Two Applications			
I. At 1.46 L/ha			
(a) 210 g/ha Fenitrothion + 210 g/ha Fenitrothion	110.4	272.8	TBM, Ag Truck, Ag Cat
(b) 70 g/ha Matacil + 70 g/ha Matacil	119.5	295.3	TBM, Ag Truck, Ag Cat
(c) 210 g/ha Fenitrothion + 70 g/ha Matacil	141.1	348.7	TBM
II. At 0.4 L/ha			
(a) 210 g/ha Fenitrothion + 210 g/ha Fenitrothion	7.2	17.9	Ag Truck Ag Cat
(b) 70 g/ha Matacil + 70 g/ha Matacil	6.4	15.9	Ag Truck Ag Cat
SUB-TOTAL	384.6	950.6	
GRAND-TOTAL	496.1	1 226.0	

*Source: Forest Protection Limited.

Table 2. Aircraft fleet used by Forest Protection Limited for Spruce budworm control in 1986 in New Brunswick.*

Aircraft Type	FPL Owned FPL Operated FPL Controlled	Dry Leased FPL Operated FPL Controlled	Contracted FPL Controlled	Total
Spray Aircraft				
TBM Avenger	9	---	---	9
Ag-Cat	---	---	8	8
Cessna 188	2	---	6	8
Bell 206	---	---	4	4
Total Spray	11	---	18	29
Non-Spray Aircraft				
Cessna 185	---	3	---	3
Cessna 172	---	26	---	26
Cessna 206	---	2	---	2
Bell 206 (Rescue)	---	---	1	1
Bell 47	---	---	2	2
Total Non-Spray	---	31	3	34

29 Spray Aircraft + 34 non spray aircraft = 63 Total

* Source: Irving, H. J. 1986. Forest Protection Limited 1986 Program Report.

were completed by the morning of June 16th. The majority of the B.t. blocks were timed for red-black spruce protection and some were not opened until June 18th. The project was completed on the evening of June 21st.

Results of Spray Program

At present, the objectives of the spray program in New Brunswick are to retain 60% or more of the current year's needles on balsam fir and 50% or more on red-black spruce. Virtually all the red-black spruce trees sampled met the foliage protection objectives regardless of treatment (Table 3). Results on balsam fir were also successful but more variable, with 69-94% of all samples meeting the objective (Table 3).

Based on the aerial defoliation survey there were about 94 970 ha of moderate and severe defoliation detected within all spray areas (Table 4). This represented 10% of the total province-wide moderate and severe defoliation, or 19% of the total area treated by all insecticides. On a treatment basis, moderate and severe defoliation was detected by the survey on 1% to 32% of the areas sprayed (Table 4). It must be cautioned that the aerial survey is influenced by many factors, and also since it is not a block-specific survey these results are more relative than absolute.

Spruce Budworm Conditions in 1986

The 1986 aerial defoliation survey was conducted in the standard manner and revealed an estimated 160 000 ha of light, 229 000 ha of moderate, and 698 000 ha of severe defoliation (Figure 2). Only 10% of the moderate to severe defoliation was inside the treated areas. Defoliation was again scattered around the Province, with largest concentrations found throughout the north-central, northwest and in the southeast. The western border, and much of the south and central parts of the Province were undamaged. The 927 000 ha of moderate to severe defoliation represent a 13% decrease from 1985, a 27% increase from 1984, and a significant 54% decrease from the 2.03 million ha in 1983.

Table 3. Number of trees sampled and precent meeting foliage protection objectives on balsam fir and red-black spruce in each treatment.

Treatment	Balsam Fir		Red-Black Spruce	
	Number	(%)	Number	(%)
TBM				
2x Matacil	481	(81)	280	(100)
2x Fenitrothion	19	(79)	141	(99)
1x Fen.+1xMat.	732	(84)	39	(100)
CHECKS	562	(44)	349	(98)
SSP*				
2x Matacil	382	(81)	145	(97)
2x Mat. (0.4 L/ha)	168	(74)	93	(100)
2x Fenitrothion	186	(69)	248	(99)
2x Fen. (0.4 L/ha)	124	(94)	100	(100)
1x B.t.	438	(82)	878	(100)

SSP* = Small Spray Planes

Table 4. Area (ha) of moderate and severe defoliation within each treatment based on the 1986 aerial defoliation survey.

TREATMENT	AREA (HA) DEFOLIATED	AREA (HA) SPRAYED	% OF SPRAY AREA DEFOLIATED
TBM			
2 x MATACIL	7 563	94 797	8%
2 x FENITROTHION	12 144	83 724	15%
1 x FEN. + 1 x MAT.	32 373	141 086	23%
Sub-Total	52 080	319 607	16%
SSP*			
2 x MATACIL	8 025	24 701	32%
2 x MAT. (0.4 L/HA)	86	6 433	1%
2 x FENITROTHION	7 636	26 652	29%
2 x FEN. (0.4 L/HA)	1 232	7 252	17%
1 x B.T.	25 911	111 462	23%
Sub-Total	42 890	176 500	24%
GRAND TOTAL	94 970	496 107	19%

SSP* = Small Spray Planes

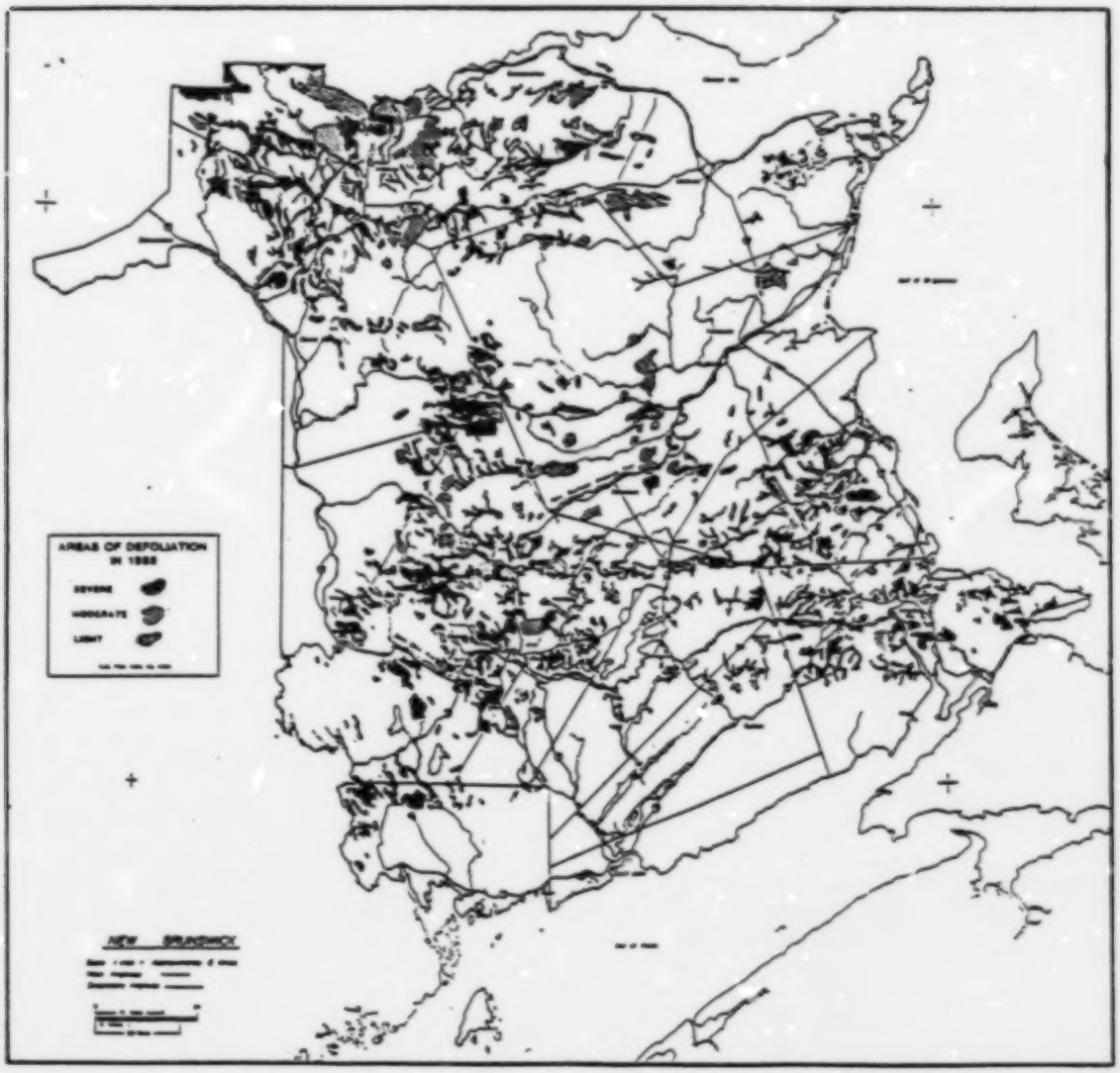

Figure 2. Areas of Light, Moderate and Severe defoliation mapped during the 1986 aerial defoliation survey in New Brunswick.

Forecast of Infestation for 1987

As noted last fall, the traditional egg mass survey in New Brunswick has been replaced by the overwintering larval or L2 survey. The year's survey has been completed and a total of 1 586 L2 sample points have been processed. Table 5 provides a comparison of forecast data since 1981 revealing an almost steady decrease in the intensity of the infestation to the point where 77% of the sample locations have low populations. Although high populations are not prevalent as in previous years, moderate populations still occur throughout much of the northern part of the province and in smaller though significant patches elsewhere. In the absence of protection and under favorable weather conditions, these populations are still capable of causing unwanted levels of damage. The total area forecast to support moderate and high populations in 1987 is approximately 1.706 million ha (Figure 3) and is a 46% reduction from the 3.15 million ha forecast last year. The forecast area of infestation has been decreasing annually since 1982 (Table 6).

Plans for 1987

Spray plans for 1987 have not been formulated at this time. Nevertheless, it does appear that a protection program will be required in New Brunswick next year. We anticipate that a combination of chemical insecticides and B.t. will again be used though the relative amounts are not known. Tentative spray plans should be known by mid-December.

Table 5. Comparison of Spruce Budworm Forecast Infestation Levels 1981-1986.

YEAR	FORECAST INFESTATION LEVEL			NUMBER OF LOCATIONS
	LOW	MODERATE	HIGH	
1981 egg-mass	591 (34%)	441 (25%)	708 (41%)	1740
1982 egg-mass	458 (26%)	512 (29%)	783 (45%)	1753
1983 egg-mass	636 (48%)	257 (20%)	423 (32%)	1316
1984 egg-mass	747 (51%)	331 (22%)	398 (27%)	1476
1985 L2	833 (56%)	503 (32%)	185 (12%)	1521
1986 L2	1216 (77%)	322 (20%)	48 (3%)	1586

Table 6. Comparison of Forecast Area (ha) of Moderate and High Infestations 1982-1986.

YEAR (N)	(N + 1) FORECAST
1982	5.30 million ha
1983	4.10 million ha
1984	3.57 million ha
1985	3.15 million ha
1986	1.71 million ha

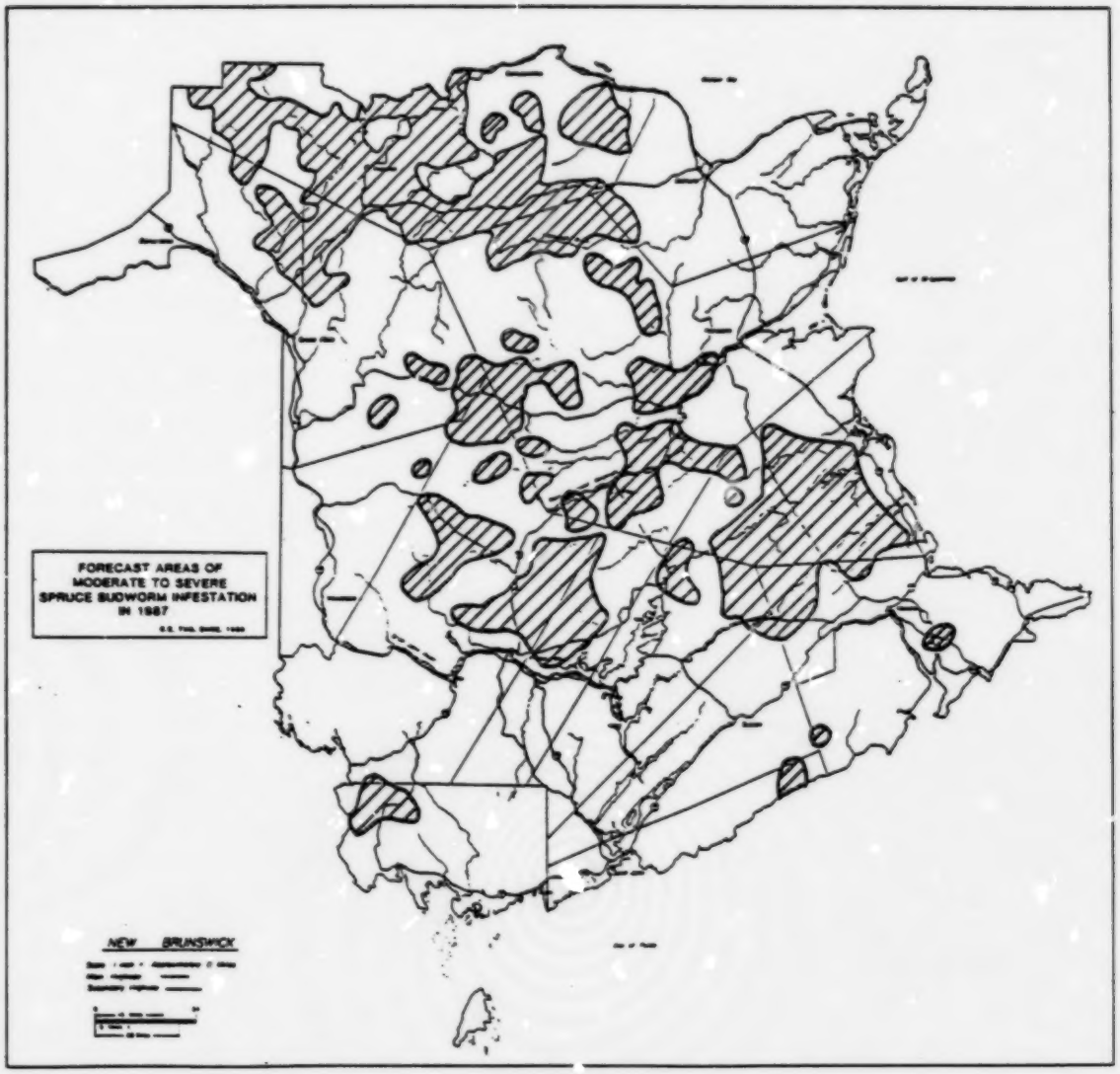

Figure 3. Forecast areas of moderate and high budworm populations for 1987 based on the 1986 L2 survey.

1986 INSECT CONTROL OPERATIONS
J. D. IRVING LIMITED

B. Brunsdon

In 1986, J. D. Irving Limited carried out insect control programs to protect its freehold lands from the spruce budworm and the spruce budmoth.

All aerial pesticide applications carried out by J. D. Irving Limited were done with spray aircraft owned by J.D. Irving Limited. These included three Rockwell Thrush Commanders and three Ayres Turbo-Thrush, each of which were equipped with four Micronair AU 4000 atomizers.

Spruce Budworm Program

The spruce budworm control program began on May 31st, and was completed by June 21st. A total of 50 320 ha were treated. The treatments are summarized as follows:

One application of Matacil 180F	:	781 ha
Two applications of Matacil 180F	:	13 620 ha
One application of Sumithion	:	2 843 ha
Two applications of Sumithion	:	19 048 ha
One application of Matacil 180F and one application of Sumithion	:	13 998 ha
One application of Dipel 132	:	30 ha

The products were applied in accordance with label directions, at the following rates:

- Matacil 180F was applied at UULV without a carrier agent at 90 g a.i./ha (0.50 L/ha).

- Sumithion was applied at 210 g a.i./ha in a total spray mix of 0.73 L/ha. Composition of the spray mix was (by volume): 23% technical fenitrothion, 3% Dowanol TPM; 3% Atlox 3409F; and 71% water.

- Dipel 132 was applied at 30 B.I.U./ha, without a carrier, at 2.34 L/ha.

Spruce Budmoth Program:

An operational spruce budmoth control program was also undertaken by J.D. Irving Limited on the Black Brook limits in 1986. This program was targeted at the adult spruce budmoth. The program was commenced on July 13th and was concluded on July 23rd. Treatments were scheduled to coincide with increases in the budmoth population as detected by pheromone traps set out in spray blocks.

Sumithion and Matacil were used in the program but application rates were reduced from the larval spruce budworm control program rates (to 105 grams a.i./ha for Sumithion and 45 grams a.i./ha for Matacil). Water was the major carrier component for both products, which were applied in a total spray mix at a rate of 0.73 L/ha.

A total of 27 161 ha was treated under the spruce budmoth control program. The area treatment summaries are as follows:

One application of Sumithion	:	7 324 ha
Two applications of Sumithion	:	7 247 ha
Three applications of Sumithion	:	6 072 ha
Four applications of Sumithion	:	3 411 ha
One application of Sumithion and one application of Matacil	:	3 107 ha

Experimental Work

In addition to the spruce budworm and spruce budmoth operational programs, J. D. Irving Limited also participated in two experimental insect control trials: a spruce budmoth larval control experiment conducted by the Maritimes Research Centre of the Canadian Forestry Service, using the B.t. formulation SAN 415; and some spruce budmoth pheromone research work conducted by the N. B. Research and Productivity Council.

EXPERIMENTAL SPRAYING

REVIEW OF RESEARCH AND DEVELOPMENT PROGRAMS CONDUCTED IN NEW BRUNSWICK IN 1986 TO EVALUATE PESTICIDES AND TACTICS AGAINST THE SPRUCE BUDWORM (Choristoneura fumiferana) AND THE SPRUCE BUDMOTH (Zeiraphara canadensis).

E. Kettela

Introduction:

In 1986 aerial spray test applications were conducted to evaluate the performance of higher quality spray equipment (Micronair AU 4000 atomizers), B.t. formulations and UULV fenitrothion against spruce budworm larvae, fenitrothion UULV applications against adults of the spruce budmoth, and B.t. against larvae of the spruce budmoth. These trials were conducted in cooperation with Forest Protection Limited, J. D. Irving Limited., the N. B. Research and Productivity Council, and the manufacturers of the pest control products. The following is a summary of the field work conducted in 1986.

1. Spruce Budworm (Choristoneura fumiferana(Clem.)).

(a) Bacillus thuringiensis Two series of trials were conducted, one with formulations of Dipel and the other with Futura. In the case of the Dipel tests the purpose was to evaluate new formulations of Dipel including the most highly concentrated B.t. tested to date, aqueous based formulations and a new oil based formulation thought to be more compatible with currently used spray formulations. In the case of the Futura tests, the purpose was to evaluate three dosages (20, 25 and 30 BIU/ha) of the currently registered Futura product, Futura FC, sprayed undiluted. In all cases assessments of efficacy included developing the relationship between spray deposit on foliage and foliage protection, which is the bottom line in efficacy determination. In

addition to this work, evaluation of a technique to quantify the deposition of B.t. on foliage was undertaken with N.B. Research and Productivity Council which was the lead agency in this work.

The four products tested were Dipel 6L, 8 NES (an oil formulation compatible with water), 8 AF(an aqueous formulation), and 12L, a highly concentrated formulation. All four products showed reasonable efficacy against the spruce budworm, and there was no signigicant difference between treatments. A clear relationship existed between deposit and efficacy, as in previous trials. This information has been forwarded to the manufacturers for registration of their product. In further association with this trial a new bioassay technique to evaluate B.T. spray deposit was successfully tested. This will enable us to evaluate spray deposit in operational blocks without the aid of a dyed spray.

Results of Futura Tests: Three dosage of Futura FC were tested and Futura was sprayed undiluted through the Micronair AU 4000 rotary atomizers. This product is very viscous but nonetheless sprayed through the nozzles and provided a deposit on foliage similar to other products. Acceptable results were obtained with all three dosages sprayed but the highest dosage provided the maximum amount of protection.

(b) Chemicals

As a continuation of the work started in 1984 further tests with the UULV application of fenitrothion (0.4 L/ha of total volume) were conducted. The work in 1986 was an operational test to verify the work previously done. Nine spray blocks in the Blackville area were so treated. Spray equipment used was Cessna 188 aircraft equipped with Micronair AU 4000 nozzles. The results clearly show that this use pattern is effective for providing effective

protection to balsam firm foliage from spruce budworm feeding. Spray deposit in these blocks tended to be higher than in small blocks treated with the conventinal spray volume rate (1.5 L/ha).

As mentioned above, the Micronair AU 4000 nozzles were used. This equipment was installed by Forest Protection Limited on their Cessna 188 aircraft. Previous wind tunnel tests by J. Picot indicated that this was a superior nozzle in its ability to produce a more desirable spray cloud. The tests conducted in 1986 demonstrated its utility.

2. Spruce Budmoth (Zeiraphera sp.)

(a) Bacillus thuringiensis Tests with three dosages of SAN-415, a new strain of B.t., were conducted in 1986 as a follow up of tests in 1985. Application of the B.t. was by J.D. Irving's aircraft to white spruce plantations. The dosages tested were 20, 25 and 30 BIU/ha. This product showed no apparent efficacy against larvae of the spruce budmoth. Larval populations of spruce budworm in the same area were affected by this product. This I believe is a function of the exposure of the insects to B.t.. Zeiraphera is a very cryptic feeder.

(b) Chemicals

Adulticide trials Field work in June 1986 in areas treated in 1985 found that the level of damage in treated blocks was significantly lower than in non-treated blocks for all treatments and dosages of fenitrotion and aminocarb. Based on this, further trials were conducted against adults of Zeiraphera Sp: in 1986. Only one dosage was used, 105 g/ha per treatment but some of the areas were treated once, some twice and one three times. The

insecticide used was fenitrothion. As in 1985 pheromone traps were used to time application of insecticide. Further, as in 1985. 24 hours after treatment adult activity in treated areas was drastically curtailed. Field work will have to be done in 1987 to follow up on the protection side of the story. This tactic seems to offer a way of effectively coping with this very difficult pest control problem.

TERRESTRIAL IMPACTS

EFFECTS OF ZECTRAN (MEXACARBATE) AND FENITROTHION ON FOREST SONGBIRDS: A SUMMARY REPORT OF CANADIAN WILDLIFE SERVICE (ATLANTIC REGION) FIELD STUDIES IN 1986

D. G. Busby, P. A. Pearce, and N. R. Garrity

Perspective

The carbamate insecticide Zectran UCZF-19 (active ingredient [a.i.] mexacarbate) is currently being tested for control of spruce budworm. Should the product become registered for that purpose there is considerable potential for it to become used over extensive areas of eastern Canadian forests. One of the primary environmental concerns regarding use of Zectran is its relatively high acute oral toxicity to birds. During the past three field seasons we have studied the effects of Zectran on songbirds under operational spray conditions. The insecticide is a cholinesterease (ChE) inhibitor. In a 1984 joint study with the Forest Pest Management Institute, Canadian Forestry Service, we concluded that the effect of Zectran on brain ChE activity in adult songbirds was minimal and that a spray dosage twice the anticipated operational one caused no serious impact. In 1985 the safety of the chemical to adult songbirds was verified and a study of the insecticide's effect on the growth and development of White-throated Sparrow nestlings under operational spraying conditions also indicated that there was essentially no effect at that level. Artifical dosing studies of free-living birds, however, confirmed that small quantities of Zectran may be lethal to nestlings. To determine the operational margin of safety to nestlings, we studied the effect of high-dose aerial spraying of Zectran in 1986. The 1984 and 1985 studies were reported in the corresponding EMOFICO reports.

Earlier formulations of fenitrothion have been found to be hazardous to songbirds under some circumstances of exposure. Previous work indicated that spray formulation (and other spray variables) may influence the impact of spraying on birds. A new formulation of fenitrothion, for use in UULV spraying, is currently being tested for use against spruce budworm. It consists of only two ingredients, 40% technical fenitrothion (Sumithion) and 60% Dowanol TPM by volume, and has been applied at a dosage of 210 g a.i./ha and a formulation application rate of 0.4 L/ha. We thought that that use pattern represented sufficient departure from conventional fenitrothion spraying to warrant investigation of its effect on birds.

Zectran (a.i. mexacarbate) - songbird studies:

(a) Growth and development of White-throated Sparrow nestlings exposed to high-dosage aerial application of Zectran.

The methodology employed in this study followed that described in the 1985 EMOFICO report except that only one of the usual two treatments for budworm control was applied. Parameters investigated were bird weight, tarsus length, wing length, and ninth primary feather length. Because nesting chronology varies considerably within a given population, spray application was timed to expose the maximum number of nestlings rather than to be optimum for budworm control.

Growth and development data were examined by comparisons of growth curves between exposed and control birds and by univariate and multivariate analyis of variance. Analysis of the four variables indicated that the growth rates of exposed birds were not significantly affected by the spray application. None of the four parameters, when analyzed separately, indicated significant spray impact. It can be concluded that Zectran, when applied at double the intended operational dosage, does not significantly affect the growth and development of nestlings of the White-throated Sparrow, considered to be a good indicator species.

(b) Mexacarbate residues in the food of songbirds

In studies of dosing of free-living White-throated Sparrow nestlings (noted in the 1985 EMOFICO report) we determined that Zectran is lethal in small amounts. The present study was initiated to address the concern that immediately following spray application, and before degradation of the active ingredient, the "pulse" of insecticide exposure would be sufficient to induce acute effects. That would be especially applicable to young nestlings which are known to be more sensitive than adults to ChE-inhibiting insecticides.

Insect samples were collected in two areas, one sprayed at a dosage of 70 g a.i./ha and one at 140 g a.i./ha. Sampling was done primarily with sweep nets but drop cloths and hand-held aspirators were also used. Both sprays were applied in early morning. Sampling was divided into four three-hour periods and done on the two days following each spray. For each three-hour period triplicate samples, each of one-to-two grams, were collected and stored in liquid nitrogen. Residue analyses were performed by K.M.S. Sundaram, Forest Pest Management Institute. Residue levels were highest in the high-dosage block and in the earliest sampling periods. A gradual decrease in residues occurred during the sampling period in both blocks but residues persisted longer in the high-dosage one. Residue levels ranged from non-detectable to 2.5 mg/kg wet weight. The results suggest that exposure through the food supply is below the level where acute effects might occur.

In summary, in several separate studies we have determined that at likely operational spray dosages Zectran is essentially non-impactive on songbirds, and that there is considerable margin of safety. Zectran and another carbamate insecticide, Matacil (a.i. aminocarb), appear to be less hazardous to songbirds that the organophosphorus insecticide fenitrothion. (See Appendix A for summary statement on fenitrothion hazards to forest songbirds.)

UULV fenitrothion study

The effect of UULV fenitrothion spraying on brain ChE activity in forest songbirds.

Spray impact was assessed by comparing brain ChE activity of exposed and control birds. Four species, representing foragers at different levels of the forest canopy, were studied. A total of 240 birds was collected by shooting (.410 shotgun). Sampling was done on the day of spray and the day following spray application for each of the two sprays. Control birds were collected in nearby unsprayed forest. Fenitrothion dosage was 210 g a.i./ha. Most species showed a decrease in brain ChE activity after spray application. The upper-canopy foraging Tennessee Warbler showed the greatest decrease; the ground-to-low-canopy dwelling White-throated Sparrow was affected the least. Anlaysis of the results indicates that overall ChE inhibition was similar to that caused by spraying of conventional formulations of fenitrothion.

Appendix A. Overview of fenitrothion hazards to forest songbirds - a summary statement

The organophosphorus insecticide fenitrothion has been used extensively in eastern Canada since the late 1960s, primarily as a spruce budworm (Choristoneura fumiferana) control agent but also in the control of other pests such as the eastern hemlock looper (Lambdina fiscellaria). When introduced it presented considerable hazard to songbirds. However, through improvements in application technology, formulation of the final spray product, and the lowering of dosages, the impact of fenitrothion on forest songbirds was reduced. The usual method of impact assessment utilizing pre- and post-spray songbird counts was then not sensitive enough to discern between spray impacts and those resulting from naturally-occurring phenomena. The resolution of the technique was inadequate in the determination of less than obvious spray impacts.

However, reports of songbird "kills" related to fenitrothion spraying continued and the Canadian Wildlife Service initiated a research project to study the mechanisms by which insecticides affect songbirds and to determine the extent to which subtle, but perhaps biologically important, effects may influence their behaviour, reproduction, and survival. Due to the great difficulty in carrying out detailed studies of reproduction and behaviour in wild songbirds it was also necessary to develop a useful monitoring tool for future impact assessments.

In order to satisfy data collection requirements for statistically valid conclusions, a representative bird was chosen as a model for detailed study. The White-throated Sparrow satisfied most criteria. It is abundant and widespread in New Brunswick, therefore offering investigators assurance that no matter in what area of the province spray projects of interest occurred, the study model would likely be present in good numbers. It nests on the ground and is relatively tolerant of human intrusion, thereby facilitating nest finding and frequent nest checks to study nestling growth and development. Its biology is reasonably well understood and presented no major difficulties. Finally, in New Brunswick, densities are concentrated in clear-cut areas where the birds may be exposed to the spray clouds like upper-canopy dwelling songbirds, which are extremely difficulty to study.

Based on the cumulative results of our work since 1978 our position on the issue of fenitrothion use for aerial control of forest pests can be summarized as follows:

(1) application of fenitrothion at the currently-used dosage (210 g a.i./ha) is marginally acceptable in terms of hazard to songbirds. The minimum impact of reduced growth and development of nestlings, although apparently not sufficient to reduce fledging success, is adequate reason to cast doubt on post-fledging survival, especially in years of unusual environmental stress such as adverse weather.

(2) when overexposure to birds happens, effects on behaviour and reproduction are pronounced. Some adult mortality occurs and there is nest desertion, desultory incubation, and reduction or elimination of singing and territory defence. Nestling mortality follows in the most affected situations and reduction in the growth and development of nestlings occurs in less affected cases. However, some birds within an oversprayed area may show none of those effects.

(3) reports of sporadic songbird mortality following spray operations almost certainly refer to the consequences of irregularities in spray applications (e.g. accidental overlapping of aircraft spray tracks, whether within or between spray blocks) and perhaps to atmospheric and terrain variables locally causing abnormally high spray deposit. Our experience is that overexposure of birds occurs frequently and it may be almost impossible to eliminate. It therefore seems that there will be some bird mortality as long as there is forest spraying with fenitrothion. Unfortunately, the extent of overexposure, and hence bird mortality, is exceedingly difficult to quantify. The total impact of fenitrothion on songbirds in a given spray operation thus remains unknown.

(4) we have developed the ability to use brain cholinesterase (ChE) activity as an indicator of spray impact on birds. The technique involves sacrificing a number of exposed and unexposed birds and comparing their brain ChE activities. We agree with and have adopted the figures produced by Patuxent Wildlife Research Center, of the U.S. Fish and Wildlife Service, that 20% depression in an individual, relative to unexposed birds of the same species, is sufficient for diagnosing exposure to anti-ChE toxins and that 50% depression can be diagnostic of mortality. However, we can now also relate ChE depression to the reproductive biology of songbirds. Thus in addition to being related to direct mortality of adults, 40% depression is sufficient to reduce nesting success to 11% from a normal value of 58% in White-throated Sparrows. Songbirds can apparently tolerate 20% depression

without significant adverse effects. At present we are working towards establishment of a figure which can be used to guide assessment of insecticide data packages submitted in support of registration or re-evaluation. For example, if a chemical induces 30% ChE inhibition in a population sample of songbirds it might not be acceptable and not approved in the registration protocol. Interestingly, fenitrothion spraying has resulted in a mean of up to 30% ChE depression in a variety of songbird species under normal spray operations, and a mean of 42% in a simulated double exposure experiment.

We therefore conclude that the current use of fenitrothion is questionable on the following grounds. It causes a reduced growth rate of nestlings under normal operational spray conditions. When overexposure of birds occurs, a variety of effects may result, including direct adult mortality, reduction or elimination of singing and territory defence, desultory incubation, nest abandonment, and reduced growth and development of nestlings; and it induces a level of brain ChE inhibition that borders on unacceptability under normal spray conditions. Because events causing overexposure of birds to the sprays, such as irregularities in spray applications and other factors causing abnormally high spray deposit locally, probably cannot be eliminated, we feel that any chemical receiving extensive use in forest pest control operations should be safe to songbirds at twice the operational dosage. Fenitrothion, as currently used, clearly does not meet that criterion.

FOREST PEST MANAGEMENT INSTITUTE STANCE ON THE USE OF FENITROTHION IN FOREST PROTECTION OPERATIONS RELATIVE TO ITS IMPACT ON FOREST SONGBIRDS

G. W. Green

Summary

This report has been prepared by the Environmental Impact Unit of the Forest Pest Management Institute because of concerns currently being raised by various agencies over the impact that the use of fenitrothion in forest spraying operations might have on forest songbirds. The report summarizes, very briefly, extensive environmental impact research on the effects of fenitrothion on forest songbirds that FPMI researchers have been involved with over the years and refers to work by others on this subject. Based on the extensive data available, it concludes that no hard evidence exists to document conclusively that conventional use of fenitrothion in forest spraying operations has a significant, negative impact on forest songbird populations.

INTRODUCTION

Fenitrothion has been used extensively for forest insect control in Canada since the mid-1960's. Over this period, a great number of field studies have been carried out to evaluate the effects of fenitrothion spraying on forest songbirds. The intent of this position paper is to briefly review the findings of these studies and state the position of the Forest Pest Management Institute on the use of fenitrothion in light of the knowledge which has been gained of its effects on songbirds.

The types of studies carried out have tended to fall into four categories:

1) Casualty searches for sick and dead birds.

2) Population studies utilizing some form of singing male or territorial mapping census to look for population responses.
3) Brain cholinesterase measurement studies.
4) Studies employing a variety of techniques (netting, banding, nest observations, oral dosing, growth measurements, time budgeting measurements) to assess the behavioral responses of individual birds or breeding pairs and their offspring.

Findings from these four types of studies are summarized below.

Casualty Searches

The threshold dosage at which fenitrothion spray casualties begin to be found has been reported to lie between application rates of 280 to 420 g/ha (Pearce 1968, Peakall and Bart 1983). Between 0.3 and 6.8 sick birds were reported found per man hour of searching following 420 to 560 g/ha sprays (Pearce 1968). Generalizations are, however, dangerous. Following a 1400 g/ha experimental spray in Quebec in 1978 Canadian Wildlife Service researchers reported only three sick birds found in 25 hours of searching, despite measurements of fenitrothion residues in foliage five times higher than normally encountered after conventional applications (Lehoux et al 1982, Morin et al 1986).

Population Studies

Songbird census techniques are strongly influenced by a number of factors such as weather conditions and migration events which may limit their sensitivity for detecting pesticide impacts. They are, however, the only methods to measure the significance to overall songbird populations of impacts documented on individuals. Large numbers of census studies have been carried out in fenitrothion treated areas using a variety of census techniques. Single and double applications of conventional (210 g/ha) and maximum (280 g/ha) allowable treatment rates have been found to sometimes produce short-lived decreases in songbird activity and minor

reductions in singing males counted or breeding territories identified, but no major impacts on overall songbird populations (e.g. Buckner and Sarrazin 1975, Buckner and McLeod 1977 a and b, Buckner et al 1977, Sarrazin 1977, Pearce et al 1979, Germain and Tingley 1980, Kingsbury and McLeod 1981). Peakall and Bart (1983) reviewed data from a large number of census studies, and concluded that although some species show decreases at 280 g/ha, many canopy feeding species do not show significant decreases in areas treated with up to 560 g/ha. Lehoux et al (1982) could not find significant differences in changes on a 1400 g/ha fenitrothion treated plot and untreated control plot in either the numbers of individual birds counted by transect census or the numbers of breeding territories identified by the mapping method.

In addition to short term impact studies, census studies have been used to draw conclusions about long term changes in songbird numbers in areas repeatedly treated with fenitrothion. Germain and Morin (1979) found the number of birds in plots sprayed annually for three years with fenitrothion and/or aminocarb comparable to numbers in unsprayed plots. Pearce et al (1979) reviewed census data for ten forest songbird species in New Brunswick over the years 1967-1976 when fenitrothion was sprayed extensively. They concluded that population trends closely parallel trends for the Maritimes Provinces as a whole and suggested that any short term impacts of fenitrothion had been compensated for by the natural resilience of songbird populations.

Brain Cholinesterase Studies

Field studies in New Brunswick have shown that conventional fenitrothion applications of 210-280 g/ha induce a moderate degree of brain cholinesterase inhibition in a proportion of the songbirds within treated areas, even though no abnormal behavior is noticeable in the birds collected for testing (Busby et al 1981, 1983). Between 16 and 62% of the birds in these studies showed brain cholinesterase depression of greater

than 20% when compared to untreated populations, while 5% of birds showed post-spray depressions greater than 50%. Following a 420 g/ha fenitrothion application 95% of White-throated Sparrows showed over 20% depression and 25% were 50% depressed or greater (Busby et al 1983). Generalizations are, however, dangerous. Application equipment has been suggested to influence the degree of effect (Busby et al 1981), and it has been suggested that results are largely descriptive of the effects of individual spray events, and that caution should be taken in making broad predictions to other fenitrothion sprays (Fudge, Lane and Associates Ltd., 1986). This caution is supported by citing differences between the findings of monitoring studies looking at songbird brain cholinesterase levels following 210 g/ha fenitrothion sprays for hemlock looper control in Newfoundland in 1985 and 1986. In 1985, 7% of birds sampled showed 50% depression or greater, while in 1986 the same level of depression was found in 38% of birds collected (Fudge, Lane and Associates Ltd., 1986).

Cholinesterase depression of 20% or more in birds is considered to be indicative of exposure to organophosphate pesticides (Grue et al 1983), while depression of 50% suggests a "life-threatening situation" (Zinkl et al 1980). Zinkl et al go on to suggest that inhibition of at least 80% is required before birds will be killed by a single oral dose of an organophosphate insecticide, but death may occur with only 50% inhibition when continuous exposure through contaminated feed occurs. Although birds that die from exposure to a cholinesterase inhibitor usually show at least 50% depression, similar inhibition in living birds does not necessarily mean those individuals will die (Ludke et al 1975, Grue et al 1983). Miyamoto (1977) reported that female Japanese Quail feeding on a high dose (50 mg/kg) fenitrothion diet for four weeks had their brain cholinesterase activity depressed by over 50%, but suffered no behavioral or weight gain effects except for a temporary reduction in egg production.

There is no doubt that field studies evaluating brain cholinesterase responses to fenitrothion applications are valuable for measuring the degree of exposure of songbird populations and the potential risk posed. But because they require destructive sampling, the biological response to depressions measured cannot be determined in terms of survival and behavior of the affected individuals. In addition, the factors leading to the measured degree of inhibition cannot be determined because it is impossible to know where and in what fashion (e.g. contact with spray cloud, through diet) that individual has been exposed. In order to better understand the causes and consequences of cholinesterase inhibition in small songbirds, laboratory spray chamber work with Zebra Finches, small cage birds, has been initiated at FPMI in co-operation with the Canadian Wildlife Service (Mineau et al in preparation). Studies planned for the near future will look for any behavioral and reproductive effects associated with exposure to fenitrothion sprays inducing measured sublethal degrees of cholinesterase depression.

Other Studies

Effects of a very high dosage (1400 g/ha) experimental fenitrothion application on forest songbirds were evaluated by a number of techniques evaluating responses of known individuals (Lehoux et al 1982). Nest observations revealed partial mortality of nestlings which was possibly due to fenitrothion in one of eight nests observed over the spray period. Twenty-six percent of 38 marked birds deemed to be residents on the spray plot were not relocated after spraying, but when those birds disappearing long enough before spraying to doubt their presence at the time of treatment were excluded from the analysis only 13% of the birds expected to be present could not be accounted for. Netting studies revealed no differences in the population structure, capture rate or appearance of fledglings between the treated and an untreated control plot. All these results indicate a surprisingly modest level of impact from this extremely high dosage of fenitrothion

(5 times the registered maximum rate). Similar studies have recently been carried out in Ontario by FPMI researchers looking at the effects of 280 g/ha applications, with particular emphasis on evaluating behavioral responses of marked individuals of three selected species (White-throated Sparrow, Magnolia Warbler and Chestnut-sided Warbler). Although the data are still being analyzed, preliminary indications suggest little evidence of impact will be found in the data which has been collected by time-budgeting, marking and netting techniques.

Researchers with the Canadian Wildlife Service in Fredericton have carried out a number of field studies looking at effects of aerial sprays and/or oral dosing on behavior, growth and survival of White-throated Sparrows. These studies are not published, but results are summarized in reports of the Committee for Environmental Monitoring of Forest Insect Control Operations (EMOFICO 1980, 1982, 1984). Evaluation of normal operational sprays of 210 g/ha revealed no effects on singing frequency of males or clutch size, hatching success or fledging rates in nests studied. A reduction of growth of White-throated Sparrow nestlings of about 10% was seen. Markedly different results were reported following a contrived over-spray of 420 g/ha followed by a 210 g/ha application several days later. This spray regime resulted in the disappearance of 26% of the parent birds, reduced parental care and territorial defence behaviors, and severely affected reproductive success.

Oral dosing studies with nestlings show that younger birds are more sensitive than older ones, and gradual exposure is less harmful than injestion of a single higher dose. Nestlings lost weight the day after dosing, but those surviving then showed weight gains greater than control nestlings, although weight at fledging remained lower. Oral dosing of adult males at a level inducing 40% brain cholinesterase depression resulted in reduced feeding of nestlings and a 3 to 5% reduction in nestling growth, despite increased feeding activity by the undosed females.

Summary Statement

Field studies have rather conclusively demonstrated that conventional fenitrothion applications do not cause population level impacts on forest songbirds, even with repeated annual treatments. On the other hand, there is considerable evidence to demonstrate that the margin of safety of fenitrothion to some songbirds is sufficiently narrow to be concerned about sublethal disturbances and impacts on individual birds of sensitive species and their reproductive success. There is also evidence that effects somewhat higher than those normally documented have occassionally been encountered, due to unknown vagaries of individual spray events. It is the position of FPMI that the current use pattern of fenitrothion will not be significant in affecting songbird population dynamics within the forest areas where it is used. Indeed, where the activities of insect pests such as Spruce Budworm, Jack Pine Budworm or Hemlock Looper threaten to significantly change the nature of the forest birds utilize for their habitat, fenitrothion spraying may serve to stabilize rather than depress songbird populations. However, in isolated areas where special values are placed upon singbirds for the aesthetic, recreational or ecological values they represent, the use of an alternative effective insecticide with a greater margin of safety to songbirds than fenitrothion may be preferable if forest insect control is necessary. FPMI is committed to continuing its work of development and testing of alternative pest control strategies, as well as seeking greater knowledge about the nature of fenitrothion's impact on forest songbirds and the factors which may allow us to reduce its effects. This includes further defining the impact of reduced cholinesterase levels on avian behaviour and growth.

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BUDWORM BEHAVIOUR AND THEIR MICROHABITAT IN BALSAM FIR DURING SPRAY OPERATIONS

P. C. Nigam

Abstract

Budworm populations in balsam fir are mostly in late third and/or early fourth instars during first-spray applications of fenitrothion in New Brunswick. Second application of fenitrothion is carried out when most of the larvae are in fourth instar and/or early fifth instar. B.t. is sprayed when larval population is in fifth instar.

A video tape was prepared in order to show budworm microhabitats at different stages of development and their behavior. It also showed where droplets of fenitrothion and B.t. impinge on the microhabitat and interact with the larvae.

Budworm larvae have a number of hairs on their body and their microhabitat is made of a very fine webbing, varying from 5um to 12um in diameter. The droplets of B.t. and fenitrothion impinge on the webs and with the help of body hairs are carried to the feeding site in case of B.t.; or larvae are poisoned directly when hairs come in contact with the droplets as in case of fenitrothion.

AQUATIC IMPACTS

THE EFFECTS OF FENITROTHION ON ZOOPLANKTON IN BOG PONDS

D. C. Eidt, W. L. Fairchild, and C.C.A. Weaver

Plankton samples, from the same bog ponds in which Fairchild and Eidt are studying effects on aquatic macroinvertebrates, were analysed. Organisms in samples collected before treatment and two dates after treatment from all four ponds were identified to the extent possible, and counted. The dominant organism in all the samples was the rotifer Keratella taurocephala.

A variety of other rotifers, and a few copepods and cladocerans constituted most of the rest of the zooplankters. Phytoplankton was not as abundant as zooplankton. Based on numbers, diversity, and richness, there were no differences among ponds that could be attributed to the treatments. This was true for total plankton, phytoplankton, zooplankton, and Keratella spp. Samples collected later in the season were not analysed because no effects of the treatments had been seen in the first two post-treatment samples.

EFFECTS OF FOREST SPRAYING ON THE INVERTEBRATE COMMUNITY OF BOG PONDS

W. L. Fairchild and D. C. Eidt

In 1986, the third year of study of the side effects of forest spraying in acidic (pH = 4.0) bog ponds near Lake George, York County, N.B., was carried out. The treatment plan over the three years was:

Pond	1984	1985	1986	
A	O	O	O	- control
B	O	T	O	- baseline then treated
C	T	O	O	- treated then recovery
D	T	T	O	- treated twice

O = No spray. T = Two fenitrothion sprays of 210g a.i./ha spaced 5 to 7 days apart.

An additional pond was treated in 1985 with aminocarb (2 x 70g a.i./ha). All sprays were applied from a boat or from the edge of the pond with a Solo™ back pack mistblower.

Fenitrothion was found in water, moss, and sediment, one year after treatment.

	June 1986		
Pond	Water	Moss	Sediment
A	ND/ND	3.0/3.6	ND/ND
B	.31/ND	8.5/11.5	ND[1]/ND[1]
C	.13/ND	3.3/3.8	ND/ND
D	.32/ND	4.5/12.0	ND[1]/ND[1]
	ug/L	pg/g	ug/g

ND= non detectable

1= traces were present (0.01 ug/sample detection limit)

Fenitrothion concentrations in water were down to 0.06 ug/L and ND six weeks after spraying in 1985. Higher concentrations in the water in 1986 indicate that some sink may be sequestering and then releasing fenitrothion back into the water. The moss is a candidate as the 1986 residue pattern in moss follows the treatment pattern from previous years.

Recovery was monitored for all ponds in 1986. Mean number of arthropods in ponds B (treated once 1985) and C (treated once 1984) were significantly lower than pond A (the control) in October. Pond D (treated twice 1984 and 1985) was significantly lower than pond A at three of four times sampled between May and October. Numbers of annelids and nematodes were high in July for the treated ponds similar to the year of treatment. Mean number of gyrinids followed the treatment pattern (D=107, B=93, C=49, A=40 gyrinids/pond) indicating some interaction between treatment and gyrinid density.

It cannot be said that the total invertebrate community of any of the treated ponds has returned to prespray densities and composition. Community structure, richness and diversity have yet to be fully compared. Preparation of detailed data set covering all three years is near completion. Results are not yet available for the aminocarb treatment. Further fenitrothion residue sampling is under consideration.

REGULATORY ACTIVITIES

OPERATIONAL BUDWORM MONITORING

W. A. Sexsmith

The New Brunswick Department of Municipal Affairs and Environment has the mandate to regulate pesticide application in the Province, including the spruce budworm spray program. Total number man hours spent monitoring this program for permit compliance was 392, with 16 incidents (complaints, etc.) investigated. Four spills or jettisoned loads occurred of which details follow.

Date	Spray Agency	Product	Amount	Location
86 05 29	Forest Protection Ltd.	Dipel	545 L	Chipman
86 05 31	Forest Protection Ltd.	Aminocarb	548 L	Boston Brook
86 06 12	Forest Patrol Ltd.	Fenitrothion	378.5 L	Clearwater
86 06 12	Forest Protection Ltd.	Aminocarb	1514 L	Tetagouche River

Because of inaccessibility or the nature of the spill, samples (water) were taken only at the Tetagouche River the same day that the spill occurred. Analysis for aminocarb showed residues of 14.25 ppb (0.1ppb detection limit), well below the LC_{50} (salmonids) of 10 ppm. No environmental impact was observed. All municipal drinking water supplies situated in watersheds that had spray activity were sampled before (for aminocarb and fenitrothion only) and after applications

took place. As in previous years, no evidence of pesticide residues (detection limits: aminocarb 0.1 ppb, fenitrothion 0.01 ppb) in these water supplies was found in 1986.

Setbacks, or buffer zones, have been utilized as a regulatory tool over the years in New Brunswick as a means to protect designated sensitive areas from impact of spray operations. The setbacks in place for 1986 are indicated below.

Setbacks for the 1986 Spruce Budworm Spray Program in New Brunswick

	Woodlands*	Woodlots**	
	H20***	H20	B.t.
Habitation	1.6 km	300 m	155 m
Lakes (> 40 ha)	400 m		
Designated major Rivers	400 m		
Open water bodies		65 m	0
Ecological reserves	400 m	65 m	65 m
Municipal water (point of extraction)	3.2 km	3.2 km	3.2 km
Blueberry fields	3.2 km	3.2 km	0

* TBM aircraft
** Agricultural type aircraft
*** Water-based chemical formulation

Setbacks for research applications, not shown, were 8 km from human habitation for a new active ingredient, and 3.2 km from human habitation for a previously registered active ingredient.

MONITORING PROGRAMS IN OTHER JURISDICTIONS

HEMLOCK LOOPER ENVIRONMENTAL MONITORING PROGRAM IN NEWFOUNDLAND.

M. Cahill

Environmental monitoring of the hemlock looper-fenitrothion spraying program has been conducted in Newfoundland in 1985 and 1986 by the Department of Forest Resources and Lands through licencing requirements of the Department of Environment.

The 1986 monitoring program was conducted on a spray block in central Newfoundland. It consisted of:

1. Songbird Monitoring

   This effort was intended to be more comprehensive than the 1985 work. The objectives were to once again use the brain cholinesterase inhibition technique to assess the average impact on songbirds of fenitrothion dosages of 210 g and 280 g under present operational conditions. Sample quotas were met and the report is expected to be released in the spring of 1987.

2. Pollinator Monitoring

   This study was also intended to be more comprehensive than the 1985 work. The methodology was repeated for the second year, however, the bloom species under study were changed to accommodate the later start-up date. A report is expected to be released in the spring of 1987.

3. Residue Analysis

   The purpose of this work was to record the variability rates in the deposition of the spray in the horizontal and vertical plane in the terrain and other operating

conditions. This information would be important in the prediction of potential ranges of impacts on the environment, especially on songbirds in areas where spary-track overlapping occurs.

A report on the residues for both the 1985 and 1986 spray programs is expected to be released in the spring of 1987.

ENVIRONMENTAL MONITORING IN MAINE

S. Oliveri

In 1983 a five year Long-Term Environmental Monitoring Project (LTEM) was initiated to measure chronic effects on the forest ecosystem from repeated insecticide exposure and ecosystem recovery. Data were collected in streams to determine the condition of aquatic invertebrate communities, leaf processing rates and brook trout production; breeding bird territories were measured annually within fixed plots and applicable forest stand data were collected. Completion of this project is expected in the spring of 1987.

ENVIRONMENTAL MONITORING AND QUALITY CONTROL OF AERIAL SPRAYING OF INSECTICIDES AGAINST THE SPRUCE BUDWORM IN QUEBEC IN 1986

P.-M. Marotte and
A. Cimon

Monitoring and Research Program

Environmental Monitoring

One of the tasks of the Service des études environnementales is to assess the potential environmental risks associated with the use of chemical and biological insecticide sprays against the spruce budworm. As a first step, this work requires reviewing the scientific literature in which the toxic thresholds of various products in the laboratory and field are addressed. Once these thresholds are known, a profile of post-spray environmental contamination in Québec must be constructed. To this end, a series of samples is taken each year during spray operations.

B.t.k. formulations contain spores capable of persisting in nature. These spores can also reproduce in suitable environments, a fact which differentiates B.t.k. from chemical insecticides. Although the literature is reassuring about B.t.k. toxicity for humans and fauna in general, and about its reproductive capacity in nature, vigilance is a must in this area. For another year, then, the Ministère de l'Energie et des Ressources (MER) considered it advisable to carry out systematic monitoring that would determine the contamination levels and behaviour of this bacterium in the environment.

Chemical insecticides also required monitoring in 1986 since the potential risks attached to their use are greater than those of B.t.k. The two applications planned for one territory were done with fenitrothion, of which the secondary effects on certain organisms are more evident, however minimal.

This paper discusses all the environmental monitoring activities carried out by the MER during the 1986 spruce budworm spray program. As well as evaluating the quality of the formulations, MER employees sampled three components of the natural environment (water, soil and air) in order to monitor the concentrations and persistence of the two insecticides.

1. Biological Insecticides (Thuricide 48LV™)

1.1 Aquatic Environments

Lakes

Two years ago, following the first major biological treatments in Québec, the MER undertook a study of the persistence of B.t.k. spores in the environment. To this end, lakes were monitored, as they are ideal for accumulation.

A total of 282 water samples were taken from 33 lakes, of which 14 were situated inside the treated areas and 19 outside. An initial series of samples was taken from each lake just prior to the 1985 spray program. B.t.k. concentrations in these samples did not exceed 0.87×10^4 C.F.U./L* The highest levels were found in the lakes of sectors that had previously been sprayed. The lowest concentrations probably resulted from aerial drift. Two to three days after spraying, high concentrations of up to 380×10^4 C.F.U./L were found in the water of lakes inside the treated areas. These levels subsequently dropped rapidly and, after 11 to 40 days, did not exceed 8.2×10^4 C.F.U./L. Quantities found in these lakes 11 months after spraying (in the spring of 1986) were similar to the pre-spray levels.

*C.F.U.: Given that colonies in a culture (analysis) can derive from one or more spores, results are expressed in colony forming units per litre of water (C.F.U./L) rather than in the number of viable spores per litre.

Traces of wind-borne B.t.k. were found in lakes within a 10 km radius of the treated areas 11 to 40 days after spraying. The maximum level measured was 0.47×10^4 C.F.U./L. At distances greater than this, B.t.k. concentrations were generally below the detection limit. In another study, samples taken from five lakes more than 50 km from the treated areas indicated that there is no B.t.k. in the natural state of aquatic environments in these distant regions.**

Lotic Environments

In 1986, as part of its study on the persistence of B.t.k. spores in natural environments, the MER continued to sample the watercourses monitored in 1985. The watercourses fell into two categories: some were streams found within the treated areas, while others were rivers which flow outside these areas but whose watershed was partially affected by the spray program.

Sampling inside the spray blocks focussed on 20 streams on 16 different plots of land. Fifteen streams were in sectors that had been treated by four-engine planes, and five in sectors treated by single-engine craft. The nine rivers sampled outside the treated areas were the Assemetquagan, Causapscal, Dartmouth, Matapédia, Milnikek, Montmorency, Quelle, Rimouski and Saint-Jean (Gaspé Peninsula). These rivers were chosen because of accessibility and the amount of spraying that had taken place over their watersheds.

A single sampling was carried out one year later, prior to the 1986 spray program. At this time, three water samples were taken at five-minute intervals from each of the 29 stations. In all, 87 samples were taken for all the watercourses in this series.

**R. Dostie, G. Parent, P-M. Marotte and S. Delisle. 1986. Concentrations de Bacillus thuringiensis dans l'eau de lacs sutués à l'intérieur et à l'extérieur des aires traitées contre la tordeuse des bourgeons de l'épinette au Québec, en 1985 Québec: Ministère de l'Energie et des Ressources, Service des études environnementales, 23p.

Another study was carried out in 1986, this time on the spatial and temporal variations of B.t.k. in lotic water. The purpose of the study was to check the homogeneity of the B.t.k. concentrations found in watercourses immediately after spraying, and to validate earlier sampling in this way. Data from this study are currently being analyzed, and a report should be published this spring (1987).

Drinking Water Supplies

Four drinking water intakes, situated between 4.8 and 9.3 km from the treated areas, were monitored during an approximate 96-hour post-spray period. Twenty-five samples were taken.

Pre-spray concentrations of 140 and 670 C.F.U./L were found in two of the four sampling stations. These stations were situated within a 20-km radius of sectors treated with B.t. in 1985. No trace of B.t. was detected at the other two intakes prior to the 1986 operations.

At all stations, weak B.t.k. concentrations ranging from undetected (U.D.)* to 7,200 C.F.U./L were found 12 to 108 hours after spraying. At one station, no trace of B.t. was found at any time during the sampling period.**

* U.D.: < 10 C.F.U./l.

**S. Delisle, G. Parent and R. Dostie. 1986. Surveillance des prises d'eau potable réalisées dans le cadre du suivi environnemental des pulvérisations aériennes d'insecticides contre la tordeuse des bourgeons de l'épinette au Québec, en 1986 Québec: Ministère de l'Energie et des Ressources, Service des études environnementales. 20 p.

1.2 Sediment and Pelecypods

To determine the presence of B.t. spores and to refine sampling and analytical methods, sediment samples were taken from two lakes in the areas treated with B.t.k. in 1985. In one of these lakes, pelecypod (mollusk) samples were also gathered. These data are currently under analysis. Depending on results, the possibility that B.t.k. accumulates in these two other elements of the ecosystem will be studied more closely in 1987.

1.3 Forest Soil

As part of the environmental surveillance program begun in 1984, B.t.k. contamination and persistence in forest soils were reassessed in 1985 and 1986. The results obtained in 1984 had shown that significant concentrations of B.t.k. spores persisted in the soil up to 11 months after spraying. In 1985-1986, research was carried out to corroborate these results and provide further details. To this end, a network of permanent stations was set up in 1985 in order to determine the persistence of B.t.k., and verify the possibility of its germination and accumulation over successive spray years.

Research concentrated essentially on the organic layers, since these are the locations of greatest biological activity. However, in order to assess the vertical distribution of deposits, analyses were also done on the mineral substrates. Finally, a study was also carried out to assess the relationship between B.t.k. and the pH level of the soil.

In 1985, 29 stations inside the treated areas and 39 outside were sampled. Eleven months later, in the spring of 1986, only stations inside the treated areas were sampled.

Pre-spray concentrations of B.t.k. varying from U.D.* to 93 x 10^4 C.F.U./g of dry weight (χ = 7.6 x 10^4 C>F>U>/g) were found in the organic substrate of stations in the treated areas.

* U.D. = 0.1 x 10^4 C.F.U./g.

Samples containing no trace of contamination all came from sectors that had not been treated in 1984. Between one and three days after spraying, B.t.k. concentrations in the organic substrate from 1.6×10^4 to 140×10^4 C.F.U./g ($\bar{x} = 28 \times 10^4$ C.F.U./g). After 12 to 39 days, these levels were from 3.6×10^4 to 120×10^4 C.F.U./g ($\bar{x} = 23 \times 10^4$ C.F.U./g). Eleven months later, residual concentrations were between 1.2×10^4 and 55×10^4 kC.F.U./g ($\bar{x} = 14 \times 10^4$).

Of the 39 sampling stations set up outside the treated blocks, 30 showed no trace of B.t. prior to the 1985 spray program. These stations were all situated in areas that had never been treated. The other nine stations, situated less than 4.3 km from sectors that had already been treated, showed concentrations varying from 0.18×10^4 to 2.3×10^4 C.F.U./g. One month after spraying, no trace of B.t.k. was found in 23 of the 39 sampled stations. In the other stations, contamination levels were close to the detection limit.

B.t.k. is distributed in the soil according to depth. Eleven months after spraying, the highest concentrations were found on the surface. It was noted that post-treatment contamination of mineral substrates increased with time.

Finally, it was observed that the spores of B.t.k. did not seem to germinate or develop in soils where all pH levels were lower than 4.9. The literature indicates that one of the optimum conditions for B.t.k. germination is a pH level higher than 4.8.

1.4 Continuous Air Sampling in Municipalities in the Vicinity of Treated Areas

The aim of this project was to assess biological insecticide (B.t.k.) drift in inhabited zones and to measure the doses to which citizens in these municipalities may be exposed.

La Tuque and the North Shore communities of Baie Comeau and Betsiamites were selected for this study. In each town, a composite sample was obtained over each 24-hour period, beginning approximately five days prior to the beginning of the spray program and ending approximately five days after the last application.

Samples were taken at a rate of approximately 25 l/min with model 88 Sierra-Misco™ samplers equipped with a filtering membrane. The pumps were set up on open, relatively flat private land. Each sampling station was operated for approximately 20 days.

In the 70 air samples taken, B.t.k. concentrations varied between undetected (< 3 C.F.U. per sample for 47 samples) and 6.68 C.F.U./m^3 (9.19 C.F.U.-min/L), which was detected in La Tuque.

1.5 Quality Control for Bacillus thuringiensis formulations

The formulations used in 1986 had been purchased the previous year. Despite the fact that they had been sampled and analyzed in 1985, they were subjected to a second, less elaborate, quality control. The 1986 control focussed on the search for pathogens and vegetative forms of B.t., and on the determination of insecticide potency.

The products used in 1986 were Thuricide 48LV™ (1985) and Futura XLV™ (1985). The number of samples taken per product is given in the following table.

Product	Barrels	Lots	Sampled Barrels
Thuricide 48LV™(1985)	270	44	74
Futura XLV™(1985)	4	3	3

The 1986 quality control on B.t.k. based formulations revealed that:

1. There are no pathogenic contaminants in these formulations. Analyses done by the Institut Armand Frappier on a series of 15 samples have confirmed the MER results.

2. These formulations do not contain any vegetative form of B.t.k.

3. Almost all (98%) Thuricide 48LV lots had an acceptable level of insecticide potency, while two out of three Futura XLV lots were found to be above the acceptable limit. Thuricide 48LV was found to be generally stable since potency was still good after a year's storage.

2. Chemical Insecticides (fenitrothion)

2.1 Rivers

During the 1986 spruce budworm spray program, the MER took 84 water samples from two salmon rivers and two major tributaries used as breeding grounds. These sampling stations were set up in the Forestville region, downstream from the treated areas, in the watershed of the Betsiamites, Laval, Ouellette and Adam Rivers. The shortest distance between the treated areas and the sampling stations varied between 1.5 and 11.0 km. Sampling was carried out for the duration of the spray program.

Maximum fenitrothion levels of 5.55 and 6.03 ug/L were detected six hours after spraying on the watershed of the Laval, Ouelette and Adam Rivers. The proximity of the treated areas and the presence of major river branches within these areas explains the results. After 12 hours, no concentration exceeded 2.84 ug/L. At this point, fenitrothion traces decreased rapidly in these rivers, and were less than 0.5 and 0.2 ug/L after 48 and 96 hours, respectively.

Concentrations in samples taken from the Betsiamites River were very low during the entire sampling period. No trace of insecticide was found in 59% of the samples.

A report on these findings is being prepared.

2.2 Drinking Water Supplies

No trace of fenitrothion was detected* in the 11 water samples taken from the only drinking water intake liable to be affected by the 1986 fenitrothion spray. This station was situated 8.8 km from the treated areas.

2.3 Forest Soil

For this project, which began two years ago, ten stations were sampled in 1986. They were all situated inside sectors treated with fenitrothion in 1985. A single sampling was carried out one year later, in the spring of 1986. A report on the findings is forthcoming.

2.4 Continuous Air Sampling in Municipalities in the Vicinity of Treated Areas

The aim of this project was to assess chemical insecticide (fenitrothion) drift in inhabited zones, and to measure the doses to which citizens of these municipalities may be exposed.

* U.D. <0.01 ug/l

The North Shore communities of Betsiamites and Colombier were selected for this study. In each town, a composite sample was taken for each 24-hour period, beginning approximately five days prior to the beginning of the spray program and ending approximately four days after the last application.

Samples were taken at a rate of approximately 30 L/min with model 88 Sierra-Misco™ samplers. The pumps were set up on open, relatively flat private land. Each sampling station was operated during approximately 35 days.

In the 71 air samples taken, fenitrothion concentrations varied between undetected (< 1.4 ng-min/L for 63 samples) and 62.7 ng-min/L (0.04 ng/L), which was measured in Betsiamites.

2.5 Quality Control for Fenitrothion Formulations

The formulations used in 1986 were identical to those of 1985, so that the same acceptable limits for fenitrothion concentrations were used in the quality control: 13.58% to 17.12% w/w, or 175/ha to 220.5 g/ha.

Analysis results show that fenitrothion concentrations in the 1986 spray formulations were within acceptable limits. The MER met the condition of the government decree concerning pre-spray verification of formulation quality.

3. Complaints and Emergency Spills

The MER received no complaint of damages or of affected health during the 1986 operations.

RECENT PUBLICATIONS:

Barber, K. N. and P. D. Kingsbury. 1987
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Burridge, L.E., M. Woodside, V. Zitko, and K. Haya. 1985. Lethality of mexacarbate and of its formulation UCZF-19 to juvenile Atlantic salmon. Chemosphere 14: 1821-1827.

Fairchild, W.L., D. C. Eidt, and C.A.A. Weaver. 1986. The effects of fenitrothion forest spray on inhabitants of the pitcher plant, Sarracenia purpurea L.. Canadian Entomologist (in press)

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